



TITLE:

Some topics on Fatou maps in higher dimensional complex dynamics(Complex Dynamics and its Related Topics)

AUTHOR(S):

MAEGAWA, KAZUTOSHI

CITATION:

MAEGAWA, KAZUTOSHI. Some topics on Fatou maps in higher dimensional complex dynamics(Complex Dynamics and its Related Topics). 数理解析研究所講究録 2007, 1537: 33-36

ISSUE DATE:

2007-02

URL:

<http://hdl.handle.net/2433/59038>

RIGHT:

Some topics on Fatou maps in higher dimensional complex dynamics

KAZUTOSHI MAEGAWA

This is the abstract of my talk in the conference held at RIMS, October 2-6 2006. The results obtained in [M] and recent related results will be explained.

We study *Fatou maps* for a holomorphic map in a compact complex manifold. Fatou maps were first introduced by Ueda in his research on dynamics in the complex projective space \mathbb{P}^k . (Fornæss & Sibony also considered such a notion in an implicit way.)

Let M be a compact complex manifold of dimension $k \geq 1$ and let f be a holomorphic self-map of M .

Definition 0.1. (Fatou maps) Let N be a complex manifold and let $\psi : N \rightarrow M$ be a holomorphic map such that $\{f^n \circ \psi\}_{n \geq 0}$ is a normal family in N . We call such ψ a Fatou map. Particularly, in case when ψ is a holomorphic disc, we call it a Fatou disc. We say that a map $\phi : N \rightarrow M$ is a limit map of $\{f^n \circ \psi\}_{n \geq 0}$ if there is a subsequence of $\{f^n \circ \psi\}_{n \geq 0}$ which converges to ϕ locally uniformly in N .

We treat two topics on Fatou maps as follows.

1 Stable dynamics in the whole space

Let M be a compact complex manifold of dimension $k \geq 1$ and let f be a holomorphic self-map of M . Since M is compact, the Remmert proper mapping theorem implies that $f^n(M)$ is an analytic subset of M for all $n \geq 0$ and there exists a number $m_0 \geq 0$ such that

$$f^{m_0}(M) = f^{m_0+1}(M) = \dots$$

We put $S := f^{m_0}(M)$ and call it *the minimal image*. Denoting by g the restriction of f on S , the map g is a surjective holomorphic self-map of S .

In this section, we treat the case when $\{f^n\}_{n \geq 1}$ is a normal family in M , i.e. the case when the identity id_M is a Fatou map. By using Bochner-Montgomery theorem, we can obtain the following criterion.

Theorem 1.1. (*[M]*) $\{f^n\}_{n \geq 1}$ is a normal family in M if and only if $\{f^n\}_{n \geq 1}$ has at least one subsequence which converges uniformly in M .

By showing that S is a holomorphic retract, the next proposition follows.

Proposition 1.2. (*[M]*) Suppose that $\{f^n\}_{n \geq 1}$ is a normal family in M . Then, S has no singular points, i.e. S is a complex submanifold in M .

Next, we consider the number of periodic points of f . We denote by $\text{Fix}(f^n)$ the set of fixed points of f^n and put

$$\text{Per}(f) := \bigcup_{n \geq 1} \text{Fix}(f^n).$$

The following theorem shows that the total number of periodic points of f is independent of f and it is regulated by the Euler characteristic $\chi(M)$.

Theorem 1.3. Let f be a holomorphic automorphism of M . Suppose $\{f^n\}_{n \geq 1}$ is a normal family in M and $\#\text{Fix}(f^n) < +\infty$ for all $n \geq 1$. Then,

$$\#\text{Per}(f) = \chi(M).$$

Example 1.4. We regard $f(x, y) = (e^\beta y, e^\alpha x)$ as a holomorphic self-map of $\mathbb{P}^1 \times \mathbb{P}^1$. Suppose $\frac{\alpha+\beta}{2\pi i} \in \mathbb{R} \setminus \mathbb{Q}$. Then, $(0, 0), (\infty, \infty)$ are fixed points, $(0, \infty), (\infty, 0)$ are period 2 points and there are no other periodic points. Hence, $\#\text{Per}(f) = 4 = \chi(\mathbb{P}^1 \times \mathbb{P}^1)$.

2 Semi-repellers outside the post-critical set

In this section, we describe semi-repelling property of forward invariant compact sets which are outside the closure of the post-critical set in terms of repelling points and non-contracting Fatou discs.

Let M be a compact complex manifold of dimension $k \geq 1$ with a hermitian metric $|\cdot|$. Let $f : M \rightarrow M$ be a surjective holomorphic map. We denote by C the set of critical points of f and put

$$D := \overline{\bigcup_{n \geq 1} f^n(C)}.$$

Definition 2.1. (Non-contracting Fatou discs) Let ψ be a Fatou disc for f . We say that ψ is non-contracting if no limit map of $\{f^n \circ \psi\}_{n \geq 0}$ is constant.

Definition 2.2. (Repelling points) Let $p \in M$. Denote by T_p the holomorphic tangent space at p . We say that p is repelling for f if $\min_{v \in T_p, |v|=1} |D(f^j)(v)| \rightarrow +\infty$ as $j \rightarrow +\infty$.

Let Δ denote the unit disc.

Theorem 2.3. ([M]) *Let E be a compact subset in M such that $f(E) \subset E$ and $E \cap D = \emptyset$. Suppose that each connected component of $M \setminus D$ which meets E is hyperbolically embedded in M . Then, there are two subsets $E^u, E^c \subset E$ which have the following properties;*

- (i) $E^u \cup E^c = E$, $E^u \cap E^c = \emptyset$;
- (ii) $f(E^u) \subset E^u$, $f(E^c) \subset E^c$;
- (iii) *Each point in E^u is repelling;*
- (iv) *For each $p \in E^c$, there is a non-contracting Fatou disc $\psi : \Delta \rightarrow M$ such that ψ is an embedding and $\psi(0) = p$.*

Moreover, if $f(E) = E$ and $E^c = \emptyset$, then E is a repeller with respect to the hermitian metric.

Remark 2.4. In Theorem 2.3, the hyperbolicity condition can not be removed.

In case when f is a holomorphic self-map of \mathbb{P}^k of degree at least 2, we can remove the hyperbolicity condition in Theorem 2.3, thanks to Ueda's normality criterion.

Theorem 2.5. ([M]) *Let f be a holomorphic self-map of \mathbb{P}^k of degree at least 2. Let E be a compact subset in M such that $f(E) \subset E$ and $E \cap D = \emptyset$. Then, there are two subsets $E^u, E^c \subset E$ which have the following properties;*

- (i) $E^u \cup E^c = E$, $E^u \cap E^c = \emptyset$;
- (ii) $f(E^u) \subset E^u$, $f(E^c) \subset E^c$;
- (iii) *Each point in E^u is repelling;*
- (iv) *For each $p \in E^c$, there is a non-contracting Fatou disc $\psi : \Delta \rightarrow M$ such that ψ is an embedding and $\psi(0) = p$.*

Moreover, if $f(E) = E$ and $E^c = \emptyset$, then E is a repeller with respect to the Fubini-Study metric.

Here we can find an interesting question.

Question. Let f, E be the same as in Theorem 2.5. When E is the support of the Green measure, E^c is empty?

This is still unsolved at present.

References

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DEPARTMENT OF MATHEMATICS

FACULTY OF SCIENCE

KYOTO UNIVERSITY

606-8502, KYOTO, JAPAN

E-mail address: maegawa@math.kyoto-u.ac.jp